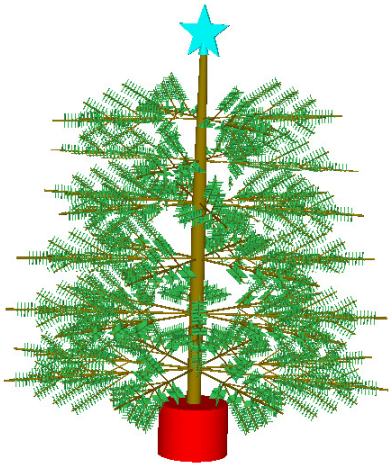
ANSWERS

News

December 2015

amec foster wheeler

Welcome to the ANSWERS 2015 Christmas Newsletter



2015 has been a very productive year for the ANSWERS development team. We have developed a BWR calculational route using WIMS/PANTHER with a BWR-builder tool. We have made good progress developing a multi-channel thermal-hydraulics module to couple to ANSWERS codes and in particular to the SP3 transient transport module that we have developed for WIMS. The burnup credit capability in MONK has been greatly improved and we have made good progress in restructuring the codes for improved parallel operation and in particular for multi-threading in MCBEND. We have developed a range of powerful uncertainty quantification tools and many have now been implemented in a development version of Visual Workshop for use with ANSWERS codes. New JEFF3.2 and ENDF/B-VVI.1 nuclear data libraries have been produced and are in the final stages of testing. RANKERN16A has been produced ready for release in the New Year, as has CRITEXUK, a code for criticality excursion analysis in fissile solutions. ANSWERS staff have presented papers at numerous international conferences during the year, as described in the news letter. Wishing you all a Happy Christmas.

Paul Smith

ANSWERS Manager

Release of WIMS Version 10A (RU1)

Peter Smith

WIMS Version 10A (RU1) is a release update of the WIMS code that will be issued to customers in the New Year. WIMS Version 10A (RU1) incorporates corrections for errors identified since the last formal release of WIMS in 2014, WIMS Version 10A (RU0), as described in Error Memos ANSWERS/WIMS/ERROR/071 – ANSWERS/WIMS/ERROR/087. The main features of WIMS Version 10A (RU1) are the availability of a 64-bit version of WIMS10 for Linux, the availability of WIMSBUILDER3A for Windows, and the inclusion of the AGR module in WIMSBUILDER3A as an evaluation feature.

If you are not currently using this latest version of WIMS and wish to have access to it, please contact ANSWERS at answers@amecfw.com

ONR Criticality Seminar

Simon Richards

On 1st December 2015 the ANSWERS Manager, Paul Smith, and the MONK Design Authority, Simon Richards, visited the Office for Nuclear Regulation (ONR) in Bootle to give a short course on Best Practice and Recent Developments in Monte Carlo nuclear criticality safety modelling. This training event was requested by ONR to give their inspectors an update on the state of the art in the field of criticality modelling.

The seminar covered three main themes: Recent Developments and Future Practice (including new features in MONK10A, future MONK developments, sensitivity and uncertainty analysis and productivity tools, modern nuclear data libraries, and burnup credit); Good Practice (including sampling guidance, input and output checking, validation and biases, and advice on the use of stochastic hole geometries); and Pitfalls and Common Errors (including common modelling mistakes, incorrect assumptions and limitations of codes and methods).

The course was attended by 14 ONR staff, including criticality safety experts, fuel and core specialists and radiation protection specialists. The attendees found the day useful and informative, and the presentations led to many interesting questions and discussions. Customers who may be interested in similar events are invited to contact ANSWERS.

2016 Key Dates

Course Dates

Introduction to MCBEND
1-4 March & 13-16 September

Advanced MCBEND
8-10 March & 20-22 September

Introduction to MONK
15-18 March & 27-30 September

Advanced MONK
22-24 March & 4-6 October

Introduction to WIMS
11-15 April & 10-14 October

Advanced WIMS
19-22 April & 18-21 October

A Date for your Diary

2016 ANSWERS Seminar
24th to 26th May at The Haven Hotel, Sandbanks, Poole

Please contact ANSWERS for more information on any of the above.

Modelling Burnup Credit with MONK10

Simon Richards

Burnup credit refers to taking credit, in a criticality safety assessment, for the reduction in reactivity of fuel that occurs with fuel burnup as a result of the net depletion of fissile nuclides and production of actinide and fission product neutron absorbers. This can give significant advantages in terms of higher fuel loading capacity in spent nuclear fuel storage and transportation.

For many years MONK has included a reactor physics capability for depletion modelling but this has been significantly improved in MONK10A by introducing the ability to overlay a burnup mesh to simplify the modelling of spatially-dependant burnup as well as the ability to do continuous energy burnup with run time Doppler broadening using BINGO, allowing the accurate temperature interpolation required to account for the temperature profile in the core. Furthermore MONK10A includes the COWL option which simplifies the process of transferring burned up material compositions from the reactor burnup model to a criticality safety model.

While these features were available in MONK10A for evaluation they have been improved in MONK10B, which will see them released as full QA features. In addition the COWL option has been enhanced to give the user more control over which nuclides to transfer between models, making it simple to do actinide only or actinide and fission product burnup credit analyses. These approaches to burnup credit offer significantly improved capacity when compared with the pessimistic fresh-fuel assumption but also retain some conservatism relative to full burnup credit by omitting some, or all, of the important neutron absorbing nuclides.

ICAPP2015 and TOPFUEL2015 Conference Attendance

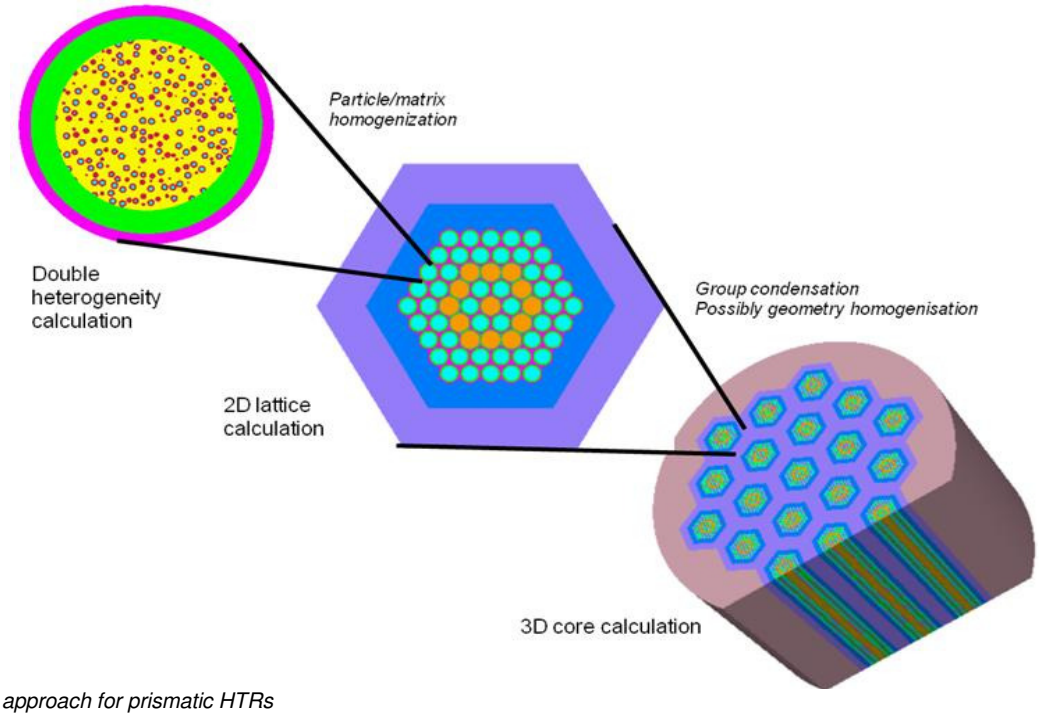
Ben Lindley

Our recent attendance at the ICAPP2015 and TOPFUEL2015 conferences highlighted the importance of a couple of 'hot topics' in the nuclear industry - Small Modular Reactors (SMRs) and Accident Tolerant Fuel (ATF).

At ICAPP2015, there were several technical presentations on the status of different SMR designs. While most 'mature' SMR designs are light water reactors - usually integral PWRs - notable alternatives are small modular fast reactors (such as GE Hitachi's PRISM design, which has been proposed for deployment in the UK) and high temperature reactors. These are all areas which are of interest to ANSWERS and where we could support customer applications.

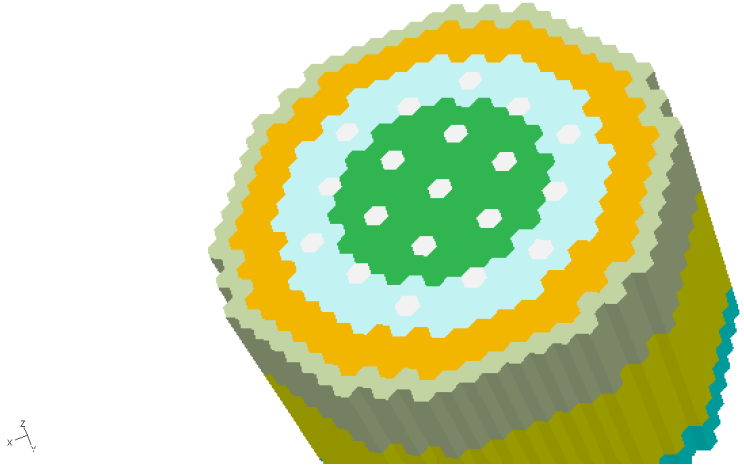
It has generally been established that the conventional 2-stage lattice transport + core nodal diffusion calculation is applicable to smaller designs of PWRs. Benchmarking SMR calculations using WIMS/PANTHER is therefore targeted for 2016, while WIMS/PANTHER is already used for SMR design studies by some customers. Ultimately, we hope to be able to perform core-scale transport calculations for SMRs, and WIMS has been gaining capability in this direction over the past few years.

For high temperature reactors, special mention should be made of the Chinese HTR-PM, which the World Nuclear Association describes as "the most advanced small modular reactor project". This is a pebble bed design, with TRISO particulate fuel dispersed in graphite 'pebbles' which are loaded within the core. Through our previous involvement in the South African PBMR project, models are available in WIMS to treat this challenging 'double heterogeneity' geometry both deterministically in WIMS and using the Monte Carlo method in MONK. In PBMRs, it is also necessary to represent the distribution of pebbles in the reactor, which is to an extent random, and for this we have developed fuel pebble packing models in MONK.



Modelling approach for prismatic HTRs

2015 has also seen significant progress in using WIMS for fast reactor applications. Through internal projects performed by summer students, and participation in a European collaborative project, we have benchmarked WIMS and MONK for sodium- and gas-cooled fast reactors and produced example models and support documentation for these systems. We aim to present our results for SFRs at PHYSOR2016.



Sodium-cooled fast reactor model

At TOPFUEL2015, there were several sessions covering ATF for LWRs, which has gained increased relevance since the Fukushima accident. We learned about the current status of different designs of ATF fuel, including some very impressive progress in Europe on Cr2O3-doped UO2 fuel for LWRs, and adding a protective coating to Zircaloy clad.

We presented a paper on reactor physics modelling of an ATF-fuelled PWR using WIMS/PANTHER, also in collaboration with Cambridge. At Cambridge, WIMS/PANTHER is being used to model the I2S-PWR, which is a ~1 GWe scale design of integral PWR being developed by a consortium lead by the Georgia Institute of Technology, with U3Si2 fuel and FeCrAl clad. At Cambridge, WIMS/PANTHER has been benchmarked for this application and is being used in design studies.

WIMS/PANTHER for BWR Applications

Ben Lindley

We have made significant progress in developing and validating WIMS/PANTHER for BWR applications in the past 12 months. While similar in many ways to PWRs (light water coolant, square assemblies, thermal spectrum), BWRs introduce several unique challenges which require modifications to the WIMS/PANTHER calculation route:

- Spectral variation in the reactor, with a low void fraction at the top of the core.
- Boiling in the reactor core leads to tight coupling between neutronics and thermal hydraulics and spectral history effects (i.e. different conversion ratio in different regions of the core, depending on the local void fraction).
- Control rod insertion at the edge of the assembly rather than in the middle.
- Control rods enter from the bottom rather than the top.
- Use of control rods for mechanical shim.
- Different assembly geometry (water rods, cruciform control blades).

In the past year, we have addressed these points by performing a series of computational benchmarks, leading up to validation against data from an operating BWR. In particular:

We have confirmed that the WIMS nuclear data is suitable for BWR applications, with results in close agreement with continuous energy MONK for various void fractions.

We have confirmed that the microscopic depletion capability in PANTHER, combined with performing calculations in WIMS at multiple coolant density and rod insertion histories, can lead to accurate representation of spectral effects with burnup.

The PANTHER thermal-hydraulic model has functionality for modelling the flow distribution in BWRs.

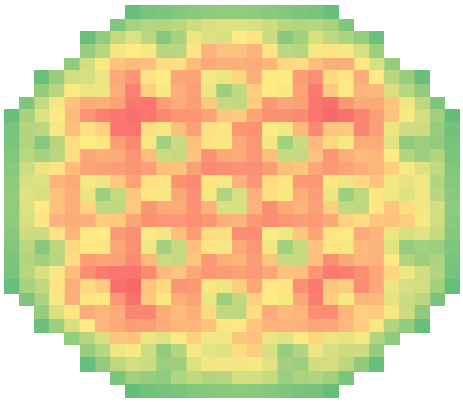
We have developed the ‘BWR-builder’ input preparation tool for WIMS, where the user provides an engineering description of the assemblies and the calculation route is automatically generated - in a similar manner to the existing WIMSBUILDER tool for PWRs, AGRs and VVERs.

We have performed a ‘clean core’ computational benchmark for the ABWR in WIMS/PANTHER, with MONK BINGO providing the reference solution, with rms errors of around 1% in assembly powers.

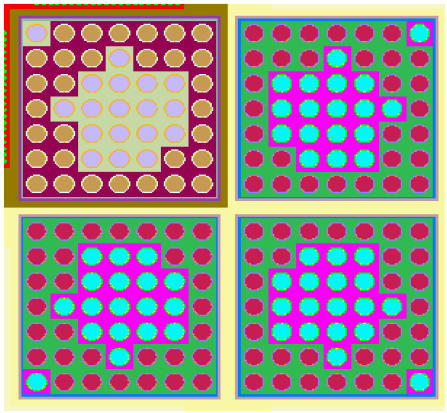
We have performed an at-power start-of-life calculation for the Peach Bottom 2 BWR, with an rms error consistent with industry standard calculations for BWRs in calculated compared to measured detector readings.

Validation and verification work is ongoing, and in particular we aim to validate the Peach Bottom 2 model over the entirety of cycles 1 and 2.

Peach Bottom 2 core (PANTHER)



WIMS supercell model of Peach Bottom 2 assemblies.

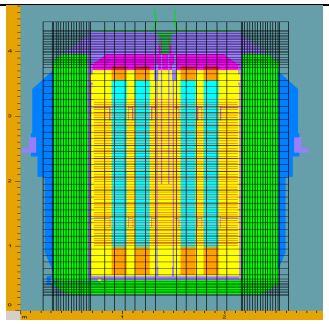


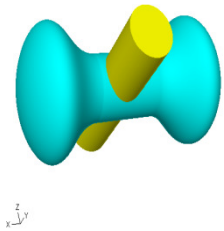
ICNC2015 Charlotte

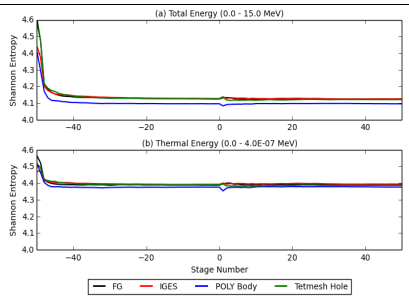
Chris Baker

Paul Smith and Chris Baker participated in the International Conference on Nuclear Criticality Safety held at Charlotte, NC. A number of ANSWERS papers were presented on: new features in MONK10, uncertainty quantification, burn-up credit and modelling fissile solutions using CRITEXUK, and Imperial College's FETCH code. There was a trend on the modernisation and parallelisation of Monte Carlo codes which is a task ANSWERS has spent much recent effort on to ensure we produce robust codes for the nuclear industry as well as future-proofing our software for modern computer architectures.

The conference provides an ideal setting to find out the trends in criticality safety, both in applications and in code development. This was an ideal platform to showcase some of the new features available in MONK10, such as unified tallies, Shannon entropy for determining source convergence, improved CAD import, runtime Doppler broadening etc.



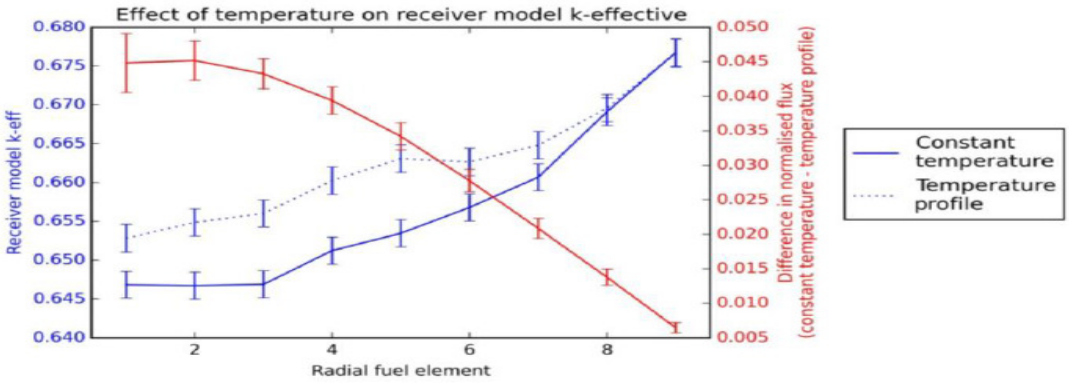




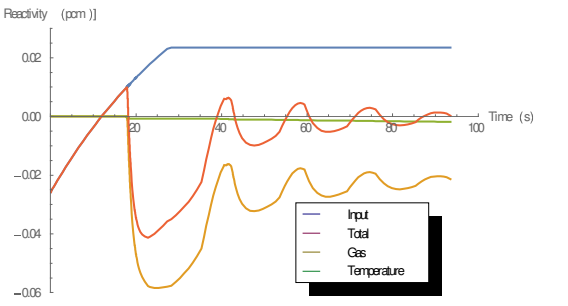
Many papers featured in the conference addressed uncertainty quantification (UQ), validation, and criticality safety best practice. Some papers focused on the move from conservative approaches to criticality safety to best-estimate plus uncertainty (BEPU), for which ANSWERS has developed tools in Visual Workshop. Many of the UQ papers focused on the current NEA UACSA benchmark IV which we are participating in. This addresses the problems associated with validating against experiments that have correlated uncertainties. This is a challenging benchmark due to the amount of computing power required.

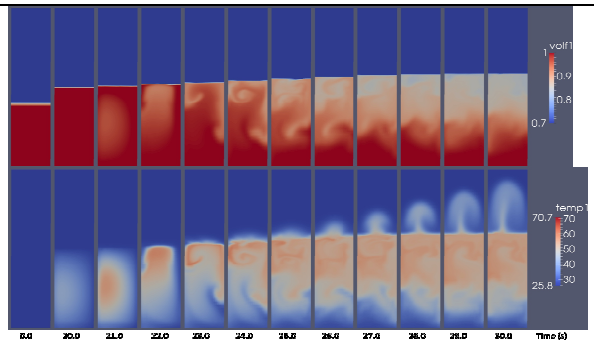
	Mean	**Standard deviation**	**97.5% confidence interval**	**Mean plus 3 sigma**	**95%/95% tolerance limit**
Nominal case	0.9689	0.0015	0.9718	0.9734	-
Sampled nuclear data	0.9718	0.0056	0.9829	0.9887	0.9848
Sampled components	0.9718	0.0027	0.9771	0.9799	0.9780
Both sampled	0.9720	0.0062	0.9842	0.9906	0.9829

There was a session devoted to burnup credit with significant interest in BUC for BWRs as well as PWRs. A number of benchmarks were discussed that can be used to complement the available validation data. Improvements in MONK BUC capability were presented, including the ability to model temperature profiles across the core which can have a significant effect on the reactivity of the discharged fuel.



The results of fast running calculations with the soon to be released CRITEXUK code were shown to give good agreement with measured data and 2D simulations with Imperial College's FETCH code give insight into the detailed behaviour of criticality excursions in fissile solutions.

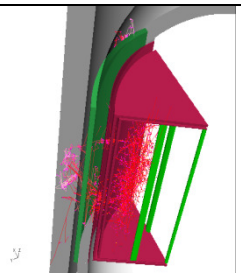


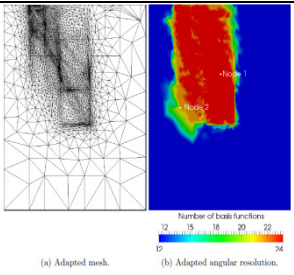


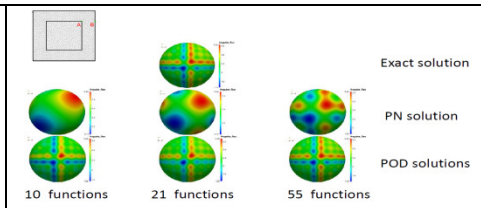
Nuclear Institute Seminar on Modelling in Nuclear Engineering

Paul Smith

Paul Smith was on the organising committee for the Nuclear Institute seminar on Modelling in Nuclear Engineering. He chaired the session on Thermal-Hydraulics and in the session on Radiation Transport and Accident Analysis he presented a paper on 'Directions in Radiation Transport Modelling'. In this he described a number of research areas that ANSWERS is working on in collaboration with Imperial College that promise to revolutionise radiation transport modelling, including: more efficient parallelisation on multi-core CPUs, GPUs and HPCs; multi-physics applications coupling neutronics, thermal-hydraulics, structural response, fuel performance and chemistry; graphical displays to aid the user to assimilate the huge amounts of data output by modern simulation software; uncertainty quantification to refine and reduce the estimated uncertainty on results (also in collaboration with MoD, Tractebel Engineering, EDF Energy, Cambridge University and Bath University); goal-based adaptivity to automatically generate optimal spatial meshing, angular representation and energy grouping to meet user-specified accuracy on chosen outputs (thus avoiding the need for time-consuming convergence studies in mesh, angle and energy); reduced order modelling (ROM) using a mathematically rigorous procedure to generate the best basis functions (POD) to provide approximate solutions (ROM models have been found to run 100,000 times faster with little loss in accuracy in some cases); hybrid Monte Carlo/deterministic methods to improve the representation of distributed quantities such as flux (for reactor physics, BUC, etc.) and dose everywhere in Monte Carlo calculations.







TRAFIC2-12a DV1 Release

Andy Smethurst

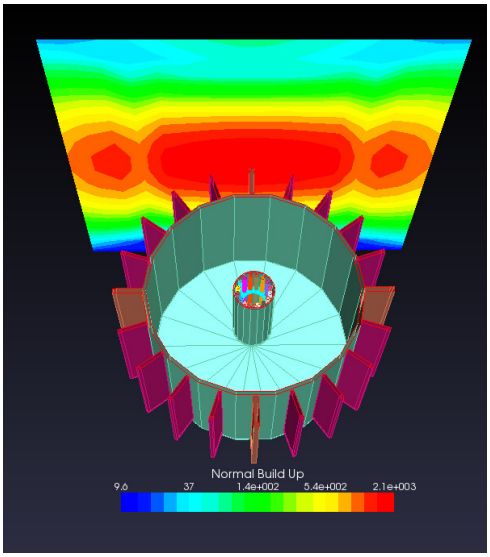
The Fuel performance code TRAFIC is about to be released as a development version on Linux and Windows. TRAFIC (TRAnsient Fuel Interpretive Code) models the behaviour of a single fast reactor fuel pin over a wide range of conditions. Various fuel types may be specified, e.g. annular or solid pellets with dishes or chamfers, or vibro fuel. The same flexibility is applied to breeder fuel with the possibility of having different types in the upper and lower regions. The fuel and 'breeder' regions are distinguished only by their user-defined chemical and physical make-up (actinide content, O/M ratio, porosity, et cetera): thus the three available types of oxide pellet could be used to model an 'axially heterogeneous' pin, with breeder in the central section, or even a pin containing three different sorts of fuel pellet. The sister codes CARTRAF and NITRAF will also be released, which model Carbide or Nitride fuel respectively.

RANKERN16A Release Update 0

Adam Bird

RANKERN16A Release Update 0 is due to be released shortly after Christmas. RANKERN 16A benefits from improved RCARD features including double precision formulae evaluation, a general power operator and additional maths operators INT, ATAN, ACOS and ASIN. There are also Logical and Character string parameters and extensions to condition statements for logical values and loop numbers. There are features to select the loop number to run from the command line and a 'history log' output option.

The major features of RANKERN16A include Activation and Fission product library support for the Unified Source and import of CAD geometry descriptions. RANKERN16A will support IGES format files and triangular polygon surface files, for example STL format, and tetrahedral mesh files. There are additional enhancements to FG including improved checking, better treatment of the torus and new triangular prism and elliptical rod FG bodies.



RANKERN Model showing a Dose Contour from Visual Workshop

Institute of Mathematics and its Applications Conference on Numerical Methods for Simulation

Chris Baker

Chris Baker attended the IMA conference on Numerical Methods for Simulation held at the Mathematical Institute at the University of Oxford. He presented a paper on the use of heuristic optimisation for criticality safety, shielding, and reactor physics applications using WIMS, MCBEND, RANKERN and MONK. This conference provided a useful platform to discuss numerical methods used from other areas of industry and which have many crossovers with the schemes we use in the nuclear industry.

The ANSWERS Seminar

The ANSWER Seminar 2016 is scheduled for 24th – 26th May, and will once again be held at the Haven Hotel, Sandbanks, Poole. Invitations will be sent out in the New Year, but it's never too early to start thinking about your presentations!

Python for Nuclear Engineering

As detailed in the Summer newsletter, ANSWERS now offers a new training course 'Python for Nuclear Engineering'. The course is made up of a number of units - ranging from basic features and programming philosophy, use of Python specific concepts and methods, through to graphing and display of data - and can be customised to your specific requirements. Recent additions to the course, which can be run over one or two days, include iPython and the Pandas library.

If you'd like more information on Python training, please contact ANSWERS.

ANSWERS Contact Details

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The ANSWERS Software Service office will be closed from midday on Thursday 24 December 2015 to Sunday 3 January 2016 inclusive.

Please note that ANSWERS customer support will not be available during this period.

Merry Christmas and a Happy New Year from the ANSWERS team